Before The
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

In the Matter of

Amendment of the Commission's Rules to Establish Rules and Policies Pertaining to a Mobile Satellite Service in the 1610-1626.5 MHz and 2483.5-2500 MHz Frequency Bands

CC Docket No. 92-166

TECHNICAL APPENDIX

TO COMMENTS OF

LORAL/QUALCOMM PARTNERSHIP, L.P.

Volume I of II

John T. Scott, III
William D. Wallace
CROWELL & MORING
1001 Pennsylvania Ave., N.W.
Washington, DC 20004
(202) 624-2500

Leslie A. Taylor
LESLIE TAYLOR ASSOCIATES
6800 Carlynn Ave.
Bethesda, MD 20817
(301) 229-9341

Attorneys for Loral/QUALCOMM
Partnership, L.P.

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SECTION 1

1.0 MSS Sharing

LQP supports the Commission's proposal regarding the sharing of spectrum in the 1610-1626.5 MHz band but asks the Commission to make certain modifications to the tentative proposals concerning the sharing of the 2483.5-2500 MHz bands. These modifications are needed to ensure that qualified CDMA systems will have adequate spectrum and downlink power to achieve needed capacity requirements.

The Commission must take steps to ensure the following:

(1) the entire 2483.5-2500 MHz band must be allocated for use by non-geostationary CDMA/MSS system(s), and policies and rules concerning the use of this band must be adopted at the same time policies and rules are adopted for the 1610-1626.5 MHz band;

(2) the PFD limit for the 2483.5-2500 MHz band must be raised by a small amount, to permit the attainment of sufficient system capacity; and

(3) the Commission must require coordination among the CDMA applicants to commence immediately so that aggregate downlink PFD limits, uplink areal spectral density limits, and polarizations are determined in a timely manner to enable applicants to proceed with finalization of system design and construction, when permitted by the Commission.

1.1 The CDMA Systems Must be Authorized Use of the Entire S-band

At least 16.5 MHz of downlink bandwidth is required for the CDMA non-GSO systems to assure adequate system capacity whether one or four non-GSO CDMA systems are operating in the same spectrum. This is because the amount of downlink spectrum and downlink PFD are the <u>primary</u> determinants of system capacity. The analysis that was undertaken during the NRM, described in Section 5.1 of the Report of the Majority of Active Participants of IWG-I, always assumed that a full 16.5 MHz would be available on the downlink for the CDMA systems. The conclusion, in the Report of the Majority, that full-band interference sharing is a feasible approach for accommodating multiple CDMA systems, was premised on the system capacities achievable when the full 16.5 MHz is utilized along with an adequately high PFD.

The Commission at Paragraph 37 of the NPRM text (FCC 94-11; cc Docket #92-166, February 18, 1994) states that it assumes that the same amount of spectrum is needed for the forward link as the return link. The Commission further states that limiting the amount of S-band spectrum awarded to CDMA operators might facilitate sharing of the S-band with existing users, (ISM, adjacent channel ITFS, and certain other foreign S-band fixed users). This logic is flawed for the following reasons, which are stated here and detailed in this section and in Section 2 of this Appendix.

(a) The entire 16.5 MHz of S-band is required due to power flux density limitations that size the capacity of the systems.

(b) The interference from ISM is low and does not constitute a problem. In any event, providing less spectrum in the S-Band to CDMA MSS systems would in no way facilitate sharing.

(c) Sharing with ITFS systems is not facilitated by band segmentation of the S-band spectrum since there is no significant interference caused by ITFS into MSS systems.

(d) Terrestrial S-band systems are protected by the PFD trigger values stated in the radio regulations. Further, analyses provided by Commission Staff of the potential interference shows that there is unlikely occurrence of interference.

Discussion:

The entire 16.5 MHz band is required for forward link (S-band downlinks) for the following reasons. As discussed below and in the Report of the NRM, the CDMA system capacities are generally limited by Power Flux Densities due to transmissions from the satellite to users (subscribers). For CDMA systems such as GLOBALSTAR, the return link (user to satellite) is not the limiting factor. Therefore, the two links are asymmetric with respect to capacity. In fact, the return link has more capacity than the forward link. As such, and at LQP's discretion, agreement with the TDMA applicant was reached concerning division of the L-band return link spectrum. This was accomplished, in the Joint Comments of LQP and Motorola, to allow the MSS proceeding to come to a conclusion, not because it makes engineering sense. In fact, CDMA systems would operate better, with lower interference, and would be easier to coordinate if the entire L-band was available to be used by CDMA applicants. The joint decision to split the L-band spectrum into a TDMA portion and a CDMA portion causes the CDMA user units, whether the band is shared or not, to operate at a higher power level requiring heavier batteries and to have higher potential for health hazard. Nevertheless, the Joint Commentors agreed to split the L-band into two pieces. This DOES NOT mean that the S-band downlink can be reduced in bandwidth. Consider a system operating at the PFD limit in downlink bandwidth of BW. This system has a capacity of "X" when operating subject to the restriction of a forward PFD limit. Since the return link, in general, has more capacity, it is possible to reduce the return link bandwidth, say by a factor of 2 as an example. If you then assume that the forward link would need the same reduced bandwidth or 1/2 BW, the following would occur. Either the PFD would be raised by 3 dB or a factor of two (2) for the same capacity, or the capacity "X" would be reduced by two (2) for the same PFD limit imposed. Therefore, the argument that assumes that the same amount of bandwidth is required in the forward link as in the return link that has been reduced to accommodate a TDMA operator which operates bi-directionally in the L-band is flawed.

Section 2 provides analysis which shows that sharing is accomplished and spectrum sharing with band segmentation with ISM, ITFS, and other S-band systems is not required.

Furthermore, the downlink analysis (Section 5.1.2 of the Majority Report of the NRM Committee) demonstrates that capacity is quasi-linear with bandwidth (capacity = (PFD + other factors)/(PFD + thermal noise + PFD from co-frequency systems)). In that section the maximum realizable capacity of each system when operating without interfering systems is calculated. Then, a second set of calculations is performed to calculate the realizable downlink capacity of the systems when operating in the presence of other interfering systems. Tables 2 through 4 in that section provide capacity calculations when six CDMA systems are assumed to be operating co-frequency , and <u>the full 16.5 MHz bandwidth is available on the downlink</u>.

In addition, Figures 1 through 6 in the NRM Report depict the impact on capacity of sharing spectrum with other systems, and also provide the variation due to PFD. These figures illustrate, that in the case of GLOBALSTAR, the capacity reduction due to spectrum sharing with other systems on the downlink, (in the case of a PFD per system of -136 dBW/m2-4kHz) is on the order of 20 percent. Reducing the amount of spectrum on the downlink <u>would significantly affect the capacities of all CDMA systems</u>. The Commission has not provided any rational technical or public interest reason for limiting the amount of S-band spectrum.

While LQP supports the Commission's proposed spectrum division in the L-band between the one FDMA/TDMA system, and the four non-GSO CDMA systems, in order to enable the Commission to adopt rules for this service and license systems within the near future, the Commission must make available and license the CDMA systems to use the entire 16.5 MHz in the S-band.

1.2 Higher PFD Limit is Required to Enable the CDMA Systems to Achieve Capacity Objectives in a Sharing Environment

As discussed above, the downlink bandwidth has a significant impact on system capacity. Linked with the amount of downlink bandwidth available is the PFD at which systems are permitted to operate. The S-band PFD also has a significant impact on system capacity and should be increased slightly to enable the CDMA systems to achieve capacity objectives when sharing spectrum.

In order to enable the CDMA systems, which will be sharing spectrum on both the uplink and downlink, the Commission should increase the PFD limit for 2483.5-2500 MHz to the following:

> -149 dB(W/m^2) in any 4 kHz band for angles of arrival between 0 and 5 degrees above the horizontal plane;
>
> -149 + 0.65(ϕ - 5) dB(W/m^2) in any 4 kHz band for angles of arrival ϕ (in degrees) between 5 and 25 degrees above the horizontal plane;
>
> -136 dB(W/m^2) in any 4 kHz band for angles of arrival between 25 and 90 degrees above the horizontal plane;

where ϕ is the angle of arrival from the satellite to any point on the earth's surface.

These limits relate to the power flux-density which would be obtained under assumed free-space propagation conditions.

In addition to increasing the capacity of the CDMA systems, the use of these higher values will enable systems such as GLOBALSTAR to proceed without the need for time-consuming and unnecessary coordinations with terrestrial systems.

The dynamic nature of the operation of the GLOBALSTAR system illustrates why the uplink and downlink do not require equal amounts of bandwidth, and in fact, why more downlink spectrum is beneficial. In an MSS system, the volume of uplink transmissions are not constrained by any regulatory limit. Although individual transceivers are governed by uplink e.i.r.p. limits, no artificial limit exists on the <u>number</u> of uplink transmissions that may occur simultaneously. In the GLOBALSTAR system, for example, the gateway earth station assigns a channel to each user, based on the current usage of all the uplink channels. This function is performed on a dynamic basis, thereby allowing uplink capacity to be used as efficiently as possible.

The downlink transmissions from the satellites are subject, not only to the capacity-limiting constraints imposed by the amount of spectrum available and operations of other non-GSO CDMA satellite systems, but also to PFD limits imposed by regulatory requirements. These PFD limits, designed to assure protection to terrestrial systems in the band, severely constrain system capacity on the downlink.

Because of the PFD limitations, the downlink and uplink are asymmetric, with the downlink having a more severe impact on system capacity. To compare the situation of the asymmetric CDMA systems to that of the symmetric Motorola system, one need only consider that IRIDIUM requires a downlink PFD of about -124 dBW/m^2/4kHz (at L-band using its TDD mode of transmission) while the PFD limit at S-band is currently -142 dBW/m^2/4kHz. The differential in the amount of capacity that can be derived per MHz at the downlink PFD of -124 and that at a downlink PFD of -142 is large.

The impact of lower PFD limits on LQP's system capacity without sharing with another CDMA system are as follows;

-139/-149	100 per cent of capacity projections
-139/-152	81 per cent of capacity projections
-142/-152	68 per cent of capacity projections

Requiring overly stringent PFD limits, when CDMA systems already are giving up capacity to accomplish the objective of spectrum sharing, produces a serious system capacity reduction that will impact LQP's ability to serve the public and to achieve its revenue requirements.

The Commission can increase the downlink PFD limit at S-band without causing increased interference into Fixed Service systems as shown in Paragraph 2.3.1. In support of the proposed PFD values, LQP notes that recent analysis of the impact of LQP's proposed operations on fixed services operating in the 2483.5-2500 MHz band demonstrates that the LQP operations, <u>at the higher PFD</u> proposed, will not cause interference. Also, at the recent international meeting of Radio communication Sector Task Group 2-2, output Document 2-2/TEMP/1(Rev.5), dated 8 February 1994, states that:

> There appears to be some sharing margin available between certain MSS and fixed service systems which have not been fully exploited. First, Non-GSO MSS satellite systems have more system design variables than GSO MSS systems. For example, Doc. 2-2/26 indicates the influence of spot beam use on non-GSO MSS satellites in improving the possibility of sharing. Also, Doc. 2-2/31 shows how system PFD levels can be improved by taking account of the orbital transmission characteristics of a particular system. Doc. 2-2/27 indicates how the PFD level can be improved as a consequence of the statistical properties of the system implemented.

The input document 2-2/27 referred to above contains the results of a simulation of interference into analog radio-relay routes from low-earth orbiting satellites of the GLOBALSTAR system. This computer simulation of possible interference from the GLOBALSTAR system into terrestrial fixed stations indicates that, at S-band, the interference levels into the FS network are below the limits stated in Recommendation 357 which defines both short- and long-term limits of interference allowed into analog angle/modulated radio-relay systems in bands shared with the fixed satellite service

(FSS). The paper concludes that

> it may be possible to impose PFD limits on MSS satellites which are higher than those specified in Radio Regulation No. 2566 (same as Footnote 753F).

These papers are discussed in more detail in Section 2 of this Appendix addressing sharing with the Fixed Service.

Analysis of digital systems, which may or may not be impacted by the higher PFD proposal, demonstrates that there may be 1 to 2 dB reduction in fade margins out of the 30-60 dB margins usually employed in those systems.

The proposed PFD values are trigger points which impose coordination. They do not mean that there is real interference.

1.3 The Commission Must Require Immediate Coordination of CDMA Service Link Spectrum Use to Facilitate Sharing

The Commission, in the NPRM, proposes a spectrum sharing scheme which allocates a portion of the uplink spectrum, and all of the downlink spectrum (addressed separately in this Technical Appendix as well as in the Comments of LQP) to be utilized on an interference sharing basis by the CDMA systems which are licensed. Because system design has an impact on interference sharing, and conversely, interference sharing has an impact on system design, it is imperative that the Commission require coordination among the CDMA applicants to begin immediately. LQP plans to begin construction of its system as soon as the Commission grants its request for waiver of Section 319(d) of the Communications Act. This waiver of Section 319(d) is sought to enable LQP to meet its construction and launch timetables and thereby expedite service to the public.

However, in order to finalize system design, coordination with the other CDMA applicants must be undertaken. As was developed in the Negotiated Rulemaking, CDMA systems can coordinate on the basis of a few parameters; however, additional information concerning system designs and operational parameters of systems sharing the band will enable each system to optimize its system for operation in a shared environment.

The Commission must take a firm stand when it issues its Report and Order in this proceeding: the CDMA applicants must commence coordination immediately. In order to commence this coordination, each CDMA applicant should be required to make available information to the other CDMA applicants on the following service link characteristics:

Downlink PFD spectral density
EIRP Areal Spectral Density
Polarization
Frequency Plans
Code Structures and Associated Cross-correlation Properties
Antenna Beam Patterns (satellite and mobile/fixed earth terminals operating in the MSS band)
Signal Burst Structures
Overall Interference Allowance into both ground and space receivers
Power control capabilities in both links

The Commission should prescribe a time certain (such as 30 days from the release of the Report and Order) for exchange of this information. Then, the Commission should require the CDMA applicants to engage in coordination for the purpose of achieving an agreed-upon recommendation of maximum downlink PFD spectral density, maximum aggregate EIRP areal spectral density and designated polarization for each system. The most important of these parameters in satellite design are the frequency plan and polarization selection. In the rules the Commission adopts, a time period for submitting these recommendations on the frequency plan and polarization should be no later than 60 days from the release of the Report and Order. Other parameters should be submitted no later than 90 days from the release of the Report and Order. In the absence of agreement, the Commission should specify that individual applicants may file recommendations to the Commission and that the Commission will issue an order with regard to these requests within 60 days of their receipt.

Stated below are proposed rules which the Commission should adopt which embody these principles. However, the Commission should not await adoption of formal coordination rules; rather it should immediately implement these procedures in its Report and Order.

With regard to coordination between the CDMA applicants and the FDMA/TDMA applicant, the Commission similarly should mandate that such coordination should commence within 30 days of the release of the Report and Order. This coordination is required to ensure that appropriate guardbands between the FDMA/TDMA system and the CDMA systems are determined within a timely manner and that the system applicants and licensees are actively engaged in coordination which may be needed to address any other matter of mutual concern.

Proposed Rules

Section 25.143 Licensing Provisions for the 1.6/2.4 GHz Mobile-Satellite Service.

(h) Intra-service coordination requirements.

(1) Applicants for licenses in the 1.6/2.4 GHz Mobile-Satellite Service have an obligation to engage in intra-service coordination, during the application process as well as after the issuance of licenses.

(2) Applicants for licenses in this service which propose to utilize CDMA must take the following actions to coordinate their systems:

(i) within 60 days after applications are placed on public notice, or as soon as practicable thereafter, exchange information on polarization choices and frequency plans.

(ii) within 90 days after applications are placed on public notice, or as soon as is practicable thereafter, exchange the following information:

Downlink PFD spectral density
EIRP Areal Spectral Density
Code Structures and Associated Cross-correlation Properties
Antenna Beam Patterns (satellite and mobile/fixed earth terminals operating in the MSS band)
Signal Burst Structures
Overall Interference Allowance into both ground and space receivers
Power control capabilities in both links

(iii) within 30 days of the receipt of the information specified in (h)(2)(ii) from other applicant(s), commence coordination. Such coordination shall be undertaken in good faith.

(iv) within 60 days of the receipt of the information specified in (h)(2)(ii), submit to the Commission proposed default values for aggregate downlink PFD spectral density, aggregate eirp areal spectral density, frequency plans, and polarizations for each system. In the absence of agreement, the individual applicants must submit their proposals for these values to the Commission.

(v) within 60 days of the receipt of the proposed default values for aggregate downlink PFD spectral density, aggregate eirp areal spectral density, frequency plans, and polarizations (whether agreed upon values or proposals of the individual applicants), the Commission must issue a ruling designating the values and polarizations to be used by the system applicants.

(vi) Any applicant which does not engage in the CDMA coordination procedure in a cooperative or timely manner, is subject to dismissal of its application by the Commission.

(3) Applicants for licenses in this service, regardless of the modulation method used, must commence coordination with other applicants, no less than 30 days after commencement of construction; or in the case of licensees, no less than 30 days after the issuance of licenses.

SECTION 2

2.0 Interservice Sharing

2.1 Sharing with the Radio Astronomy Service

GLOBALSTAR proposes to operate in the L-Band MSS allocations which are co-primary with the Radio Astronomy Service (RAS). GLOBALSTAR will protect the RAS within the 1610.6-1613.8 MHz band in accordance with the proposed rule Section 25.213 (a) (1) with one proposed modification described later in this paragraph. GLOBALSTAR intends to protect the RAS by not operating co-frequency with the RAS when a GLOBALSTAR Mobile Earth Station (MES), also defined as a user terminal, is within the proposed protection zones. GLOBALSTAR may also request smaller fixed protection zones and/or beacon actuated protection zones if agreement can be reached with the Electromagnetic Spectrum Management Unit based upon further study. The GLOBALSTAR Gateway Earth Stations will have the ability to determine the position of the GLOBALSTAR MES after its first transmission. Since the Gateway controls both the operating frequency and transmit power level of the MES, the Gateway will reassign the MES operating frequency to a frequency above 1613.8 MHz should the MES be within the protection zone at the time of the initial MES transmission.

LQP proposes that the last sentence of paragraph (v) of proposed rule Section 25.213 (a) (1) be replaced with the following:

> *The mobile-satellite system shall be capable of terminating operations in this band within the first position fix of the mobile terminal either prior to transmission or based upon its location being within the protection zone at the time of initial transmission of the mobile terminal.*

Agreements with CORF will be obtained as to smaller protection zones around the RAS sites when the GLOBALSTAR MES operates above 1613.8 MHz. These smaller protection zones will be a function of the MES out-of-band emission levels, the MES operating center frequency and anticipated propagation losses. In order for reassignment of a MES user to a frequency out of the RAS band to be a viable solution for MSS systems operating in the lower portion of the 1610 to 1626.5 MHz band and within the co-frequency protection zone limits, sufficient spectrum above 1613.8 MHz must be available where adequate frequency separation between the MES carrier frequency and the RAS band edge can be attained and allow for reasonably close-in operation to a RAS site. If GLOBALSTAR is limited to only 8.25 MHz from 1610 to 1618.25 MHz, then there will only be about 3 MHz between the RAS and the band edge of the MES emission. Even with reasonable MES out-of-band emission performance, a 3 MHz separation to the highest available channel may be insufficient to achieve acceptable reduced protection zone radii. It is proposed that sufficient spectrum be available to locate MES users well above 1613.8 MHz such that protection radii about non-VLBA and VLBA sites would typically be less than 10 km and 3 km, respectively.

While the GLOBALSTAR MSS satellite will not operate its service downlink in a secondary allocation, LQP agrees with the proposed rule Section 25.213 (a) (2). Finally, the GLOBALSTAR MSS satellites operating in the 2483.5-2500.0 MHz band will control their emissions in the 4990-5000 MHz band under all operating conditions in accordance with proposed rule Section 25.213 (a) (3).

2.2 Sharing with the Aeronautical Radio navigation and Radionavigation-Satellite Services

(1) Aeronautical radionavigation coordination is an uplink issue, and as such, is coordinated on a country-by-country basis. In the U.S., this proceeding is dealing with the prior Article 14 coordination with the Russian Federation and the new MSS systems being allocated.

(2) It is not at all clear that a GNSS which requires inclusion of GLONASS will be adopted by the FAA and the U.S. Government. The 1992 reports of the FAA indicated that GNSS might include GLONASS for integrity checking; however, recent 1994 RTCA documents seem to favor wide area augmentation systems (WAAS) to accomplish the integrity check (as shown in Attachment 12). This document does not mention GLONASS.

(3) The State Department is currently coordinating, under Article 14, the GLONASS transmissions in the U.S. This is required due to the now-primary status of Radio Astronomy. It has been announced by the Russian Federation that they plan to move GLONASS frequencies well below the 1610 MHz MSS operating lower boundary by 1998.

(4) Thus, it is unlikely that sharing with Aeronautical Radio Navigation Services is required.

(5) Therefore, it is not necessary for the FCC to adopt an interim or transitional plan as discussed in the NPRM. Indeed, this whole issue is (and should be treated as) a matter of coordination between MSS operators and the aviation community.

2.2.1 Protection of the Global Navigation Satellite System

For the unlikely case that sharing would be required with GNSS, the following information is provided. During the NRM the aviation community stated that they seek to use the Global Navigation Satellite System (GNSS) for en route, oceanic, terminal, and non-precision approach navigation. They envision that GNSS may provide the sole means of aeronautical radio navigation from gate to gate. Also envisioned is that both GPS and GLONASS may be integral parts of GNSS which may become the sole long-term means of aeronautical navigation both internationally and domestically in the United States. LQP believes that protection criteria could be developed for GNSS as a system. However, protection criteria based on each individual GLONASS Satellite measurement would be overly protective. Such an approach could stifle or severely hamper the development of existing or planned services operating in frequency bands adjacent to the aeronautical radio navigation service allocation, such as MSS. Because MESs operating in the 1610-1626.5 MHz MSS allocation are not the only sources of potential interference, GNSS system design should be developed to be more robust in an interference environment. The following factors must also be included in developing any GNSS protection criteria.

- The aviation community has not demonstrated that corruption of a single measurement from either a GPS or GLONASS satellite will cause harmful degradation in the ability to navigate. Since multiple measurements from several satellites in GPS and GLONASS satellite constellations are available, LQP believes that the ability to navigate will not be impaired. Therefore, as requested by the Commission, LQP is presenting in paragraph 2.2.4 its proposed methodology on how to develop protection criteria for GNSS.

- The GLONASS Administration has filed a document[1] in November 1993 with the ITU stating that it has entered into an agreement with the Inter-Union Commission on Frequency Allocations (IUCAF) concerning GLONASS frequency usage and the RAS. The GLONASS Administration intends to exclude the main emission of its narrowband code into the RAS 1610.6-1613.8 MHz band immediately, and, states that, "from 1999" the main emission of its broadband codes will also be excluded. The Russian Federation has negotiated similar agreements[2] with Australia and Japan to completely eliminate interference to the RAS in the 1610.6-1613.8 MHz band "by 1998."

- This GLONASS frequency plan revision is a major system modification and will greatly impact the design and manufacture of avionics hardware compatible with

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1 ITU World Radio communication Conference, Document 43-E, 16 November 1993.

2 IUCAF Document No. 398, 17 September 1993.

GNSS. Potential GNSS receiver manufacturers should be made aware of this frequency change as well as interference mitigation techniques that could influence receiver design. Also effected by this change is the ability of GNSS to co-exist with other services such as MSS, in adjacent frequency bands.

- Less than a full constellation of GLONASS satellites is required in order to maintain integrity checks. Even if implementation of the GLONASS frequency plan is delayed, there should be sufficient GLONASS satellites available to populate the constellation with 12 satellites operating in an anti-podal manner on channels 1 through 6 for GNSS operability. This scenario of 24 GPS and 12 GLONASS satellites provides the desired GNSS system integrity, as shown in Attachment 1. GLONASS satellites operating above channel 6 would not be utilized by GNSS receivers since they are not required. As the GLONASS constellation becomes populated with satellites operating on channels from -6 to -1 (corresponding to carrier frequencies of 1598.625 to 1601.4375 MHz), the availability of GNSS satellites would only increase.

In summary, it is LQP's position that GNSS protection criteria should be developed based upon the planned revision of the GLONASS frequency plan to place all carrier frequencies below 1605.5 MHz by 1998. With the new 3rd generation of GLONASS satellites starting to be launched in 1994, there certainly will be sufficient GLONASS satellites operating below 1606 MHz, almost immediately, to allow for a 36 satellite "GNSS" constellation until the GLONASS frequency plan is fully implemented. As shown in paragraph 2.2.4 there will be sufficient satellites upon which to navigate that operate below 1606 MHz. This approach eliminates the need for any interim spectrum sharing plan. Until the revised GLONASS frequency plan is completely implemented, any use of GLONASS satellites operating above 1606 MHz will be protected as described in paragraph 2.2.3. The Commission should not inhibit the planned deployment of MSS systems and the utilization of the entire 1610-1626.5 MHz spectrum by adopting rules protecting portions of the GLONASS System not required to achieve navigation objectives.

2.2.2 Protection of GPS

At the NRM it was agreed by MSS operators that protection should be afforded to GPS. LQP believes that protection should be afforded to GPS both as a stand alone system and may be required for GNSS. A protection criteria was developed by the aviation community during the NRM and, after much discussion, was agreed to by the MSS operators. This NRM protection level is as mentioned in the Commission's proposed rule Section 25.213 (b) and applies only over a nominal 2 MHz bandwidth at the center of the GPS L1 transmission. This value is a stand alone value to protect each measurement of a GPS satellite and, as mentioned in paragraph 2.2.1, its requirement has not been validated for GNSS protection.

At the present time the GPS Joint Program Office of the Department of Defense has tasked the Electromagnetic Compatibility Analysis Center (ECAC) to conduct a test and analysis program to determine the potential for EMI interference from MSS systems into military GPS receivers and, possibly, GLONASS receivers. The MSS applicants were asked to provide preliminary MES emission information for their system in March 1994. There is concern among MSS applicants about interpretation of test results. No agency has demonstrated that corruption of a single GPS measurement will cause harmful degradation. Developing protection criteria on a single measurement basis, instead of the ability to navigate, is inappropriate and inconsistent with the Radio Regulations.

In lieu of any definitive measurements or analysis by the aviation community, LQP proposes that the proposed rule Section 25.213 (b) be modified to protect the radio navigation-satellite service so as to impose reasonable unwanted emission requirements on the development of MES units for use in MSS systems. This emission data was formally submitted to the ECAC test plan coordinators through the Commission's representative. This data is representative of the performance of low cost consumer user terminals and has broadband noise levels comparable to today's cellular user terminals. The broadband out-of-band emission value of -50 dB(W/MHz) being proposed is the same as that sent to ECAC. This represents a reduction of 59 dB over the allowable[3] in-band e.i.r.p. density level of -15 dB(W/4 kHz) which, when related to a 1 MHz bandwidth, becomes 9 dB(W/MHz). The LQP proposed unwanted emission levels are significantly more stringent that the Commission's existing rules Section 25.202 (f) and Section 22.106 on emission limitations for stations operating in the Fixed-Satellite Service or Mobile Service, respectively. There is neither data nor analysis supporting a further reduction in unwanted emissions.

Consequently, in order to protect GPS, LQP proposes the following change in Section 25.213 (b) (Note: additional changes are proposed in paragraph 2.2.3):

In the first sentence the value "-70 dB(W/MHz)" should be replaced with "-50 dB(W/MHz)"

GPS use for aviation will be further enhanced by the Wide Area Augmentation System (WAAS) being developed by the FAA, WAAS can provide additional coverage equivalent to up to six orbiting satellites.[4] This capability will add the desired integrity

[3] Per proposed rule Section 25.213 (c) (1).

[4] RTCA Digest No. 98, ISSN No. 0193-4422, January - March 1994.

capability to the GPS system in a manner similar to the integrity capability that GLONASS adds to GNSS. WAAS will require 24 ground monitors and at least three geostationary satellites.

2.2.3 Protection of GLONASS

Presently GLONASS has about twelve satellites operating providing valid information. These satellites are located in planes 1 and 3 only and have their center frequencies on channels 12 and below plus channels 22, 23, and 24. Some of these higher frequency channels are operated in an anti-podal manner. Channel 12 operates a center frequency of 1608.75 MHz and channels 22, 23, and 24 operate at center frequencies of 1614.375, 1614.9375 and 1615.5 MHz, respectively. By January 1, 1999 or earlier, the Russian Federation plans to implement its revised frequency plan which would then place the highest and lowest carrier frequencies for GLONASS at 1605.375 and 1598.625 MHz, respectively. By then, properly designed GNSS avionics' receivers anticipating such a revision will have already included filters such that they reject signals above 1606 MHz. Failure to properly implement these filtering requirements could lead to degraded performance of GNSS receivers. This upper frequency is sufficient to receive the C/A code for navigation purposes. Note, that the corresponding low end frequency sufficient to encompass the C/A code will be 1598 MHz. As will be shown in paragraph 2.2.4 there will be a sufficient number of GPS and GLONASS satellites, such that, the existing channels 22, 23, and 24 are not required for GNSS navigation.

- The US government should take the position that it will not impose stringent <u>temporary</u> requirements on new MSS systems. LQP's proposed rule revisions provide protection to the U.S. users of the GLONASS component of GNSS below 1606 MHz as well as GLONASS above 1610 MHz. This approach eliminates the need for any interim spectrum sharing plan.

- Like GPS, the GLONASS Federation (the Group Filing with the ITU) similarly has not demonstrated that corruption of a single GLONASS measurement will cause harmful degradation in the ability to navigate. Developing protection criteria on a single measurement basis, instead of the ability to navigate, is faulty system engineering.

- Protection of the GLONASS portion of GNSS from out-of-band emissions from an MES operating in the MSS band should only be available after GLONASS revises its frequency plan which should be on or before January 1, 1999. This revised frequency plan would place the highest frequency carrier at or below 1605.375 MHz. Since the FAA has stated that only the

C/A code needs to be protected, the protection criteria should only cover MES emissions below 1606 MHz.

- LQP believes that it would be advantageous to both the GLONASS Federation and MSS applicants if they were allowed to participate in GLONASS related discussions prior to any agreements being made between the US and Russian governments.

In lieu of any definitive measurements or analysis by the aviation community, LQP suggests that the proposed rule Section 25.213 (b) can be further modified to afford protection to GLONASS. These emission limits should be no more stringent than that proposed for GPS protection and would be eliminated if GLONASS did not become a major integral component of GNSS.

Therefore, LQP proposes the following composite change to the first sentence in proposed rule Section 25.213 (b) to encompass both GPS and GLONASS as part of GNSS:

> *Protection of the radio navigation-satellite service operating in the 1559-1610 MHz band. Mobile Earth stations operating in the 1610-1626.5 MHz band shall limit out-of-band emissions in the 1574.397-1576.443 MHz band and the 1598 to 1606 MHz band so as not to exceed an e.i.r.p. density level of -50 dB(W/MHz) averaged over any 20 ms period.*

With this protection afforded the GLONASS component of GNSS, LQP proposes that the last two sentences of proposed rule Section 25.213 (c) (1) be deleted and that the first and, now, only sentence be modified to read:

> *(1) Mobile-satellite Earth stations transmitting in the 1610-1626.5 MHz band shall limit e.i.r.p. density levels to no greater than -15 dB(W/4 kHz) on frequencies being used by systems operating in accordance with International Radio Regulation RR 732, and to no greater than -3 dB(W/4 kHz) on frequencies that are not so being used.*

2.2.4 Assessment of GLOBALSTAR Emissions on GNSS Navigation Performance

An assessment of GLOBALSTAR MES emissions on GNSS receiver navigation performance has been performed.[5] This assessment focused on the operational impact

[5] See Attachment 1, Assessment of MES-induced RFI on Hybrid GPS/GLONASS Aviation Receivers, April 29, 1994, Sat Tech Systems.

of MES emissions on user navigation performance relative to generally accepted standards of Required Navigation Performance (RNP) as a function of user phase of flight. Analytic refinement is possible and desirable in many areas:

1. The definition of RNP is evolving. Internationally, the ICAO All Weather Operations Panel (AWOP) is attempting to forge a broad consensus on the definition of RNP. Domestically, the FAA is initiating an effort to redefine the basic requirements documents for the National Airspace System in terms of RNP -- the precise definition of RNP, and threshold levels for each phase of flight, are being refined through analysis and consensus.

2. MES operating characteristics are projections. The characteristics assumed herein are subject to refinement. In particular, some additional rolloff may exist in the far out-of-band MES emission spectrum.

3. GNSS receiver operating characteristics and performance requirements should be improved. The prior requirements were driven by formal specifications, which have ignored advancements in technology and normal engineering margins. In particular, the analysis reported here assumes that navigation performance would be lost at J/S ratios that marginally exceeded the ARINC Characteristic 743A- 1 specifications. Therefore, revised specifications which would improve MSS sharing are required, as discussed by ARINC at the NRM.

4. GNSS constellation expected performance levels are projections. As operational confidence in GNSS builds over time, and as historical experience dictates, assumed failure rates would be adjusted. Further analysis is also required to extend currently-available performance data, which were derived from assumptions that do not precisely match projected GNSS operations scenarios or evolving certification requirements.

5. Future GNSS receivers may incorporate enhanced signal rejection technologies. The specifications for GNSS receivers that will operate in conjunction with WAAS, and provide true sole means navigation capability via GNSS, are currently being developed. Interference assessment analyses are ongoing in the aviation community, and RFI mitigation techniques are being evaluated with an eye toward enhancing GNSS receiver robustness. These mitigation techniques include filtering, revisions in the A/D conversion circuitry, and others.

In spite of these influences, an initial worst case MES impact assessment has been completed. The US requirement for barometric aiding (via TSO C129) significantly improves the expected level of performance of the most disadvantaged user in US airspace. From a visibility standpoint, a full GPS constellation with two additional geosynchronous spacecraft is sufficient to satisfy all accuracy, availability and integrity requirements in all phases of flight except precision approach. Similar performance can be achieved with a full GPS constellation and six additional GLONASS or GPS satellites operated in a coordinated manner with GPS. The expected incidence of satellite failures and short-term outages (e.g., due to maneuvers) will increase the demand for satellites. However, reliability studies indicate that only a few more satellites will be required. These studies need to be refined and extended with a specific focus on GLONASS, lower mask angles (5 degrees) and barometric aiding; nevertheless, data available to date indicate that acceptable performance can be maintained with GPS plus one-fourth to one-half of the GLONASS constellation. In US airspace, it is important to recognize that certificated GNSS receivers will incorporate barometric aiding, and will have additional ranging signals (and integrity information) from typically two additional geosynchronous spacecraft in the timeframe of GLOBALSTAR operations. The impact of ground-derived integrity data on system performance was not included in the analysis reported here, but would be expected to significantly improve performance and reduce constellation requirements.

From an availability standpoint, there is no assessed requirement to track GLONASS satellites operating on channel assignments above 1606 MHz. The current GLONASS frequency plan provides six spacecraft operating channels containing the C/A code below 1606 MHz. With anti-podal assignments, GLONASS would offer an availability for integrity benefit equivalent to approximately 4 geosynchronous spacecraft. However, as few as two geosynchronous spacecraft were shown (in section 4 of Attachment 1) to satisfy sole means availability requirements in all phases of flight, as well as accuracy/availability/integrity/continuity requirements for en route, terminal area and NPA operations (note: Category I precision approach and surface operations require a differential overlay to enhance accuracy, and Category I precision approach also benefits from a differential overlay to enhance integrity. A WAAS would also provide additional ranging signals to enhance availability further.)

The conclusion of the MES impact assessment is that there is no operational impact in en route airspace, terminal area airspace and for surface operations with GLONASS operating below 1606 MHz. For approach operations (non precision approach and Category I precision approach), Continuity of Service may be affected under a conservative set of analytic ground rules. This occurs in cases where a GNSS user relies on GLONASS during the approach to provide the needed additional integrity assurance for safe operations. This is not a likely mode of operations in the United States, although it may exist elsewhere. Furthermore, within the United States and adjacent regions, planned augmentation such as the WAAS will be sufficient to support sole means navigation down to Category I minimal without reliance on GLONASS.

For users who choose to depend on GLONASS in lieu of, or in addition to the WAAS, a potential interference mode exists. For these users, the presence of an active MES close to the extended runway centerline in a narrow region approximately 0.75 miles from runway threshold, operating in its maximum power condition (normal + 10 dB) could lead to loss of some GLONASS signals and, therefore, potential loss of navigation system integrity (note that navigation guidance is not lost at this point, or even necessarily degraded; however, the user is not *assured* of its veracity). In this situation, the user's avionics could potentially declare an integrity alarm. Whether an integrity alarm is actually declared depends on numerous real-time parameters as well as the possible existence of analytic navaids such as inertial reference systems, pseudolites, etc. It is emphasized that almost any change in the underlying assumptions for this scenario would eliminate the potential for operationally significant impairment. These changes could include: (1) reliance on the WAAS; (2) reliance on WAAS ranging signals and on a local DGPS correction and integrity broadcast; (3) less than full power MES operations; (4) GNSS antenna directive gain less than -5 dBi toward the MES; (5) airframe or environmental shielding; (6) GNSS signals above minimum specified received power levels; or (7) GNSS receiver performance that exceeds the conservative ARINC 743 A-1 J/S specifications.

This preliminary assessment supports LQP's position that:

1) GLONASS satellites operating on channels 1 through 6 in an antipodal manner are sufficient to provide GNSS with the desired integrity,

2) Completion of the GLONASS constellation on channels -6 through -1 will continue to improve satellite visibility statistics, and

3) The LQP proposed MES eirp density limits provide a high confidence level that the MES units will not interfere with aviation users ability to navigate using GNSS.

2.2.5 Summary of Sharing with the Aeronautical Radio navigation and the Radio navigation-Satellite Services

The following offers both a summary of the proposed LQP comments on sharing with Aeronautical Radio navigation Service plus suggestions for negotiations with the Russian GLONASS Federation. LQP proposes that the US Government take appropriate action to ensure the following:

- As part of GNSS both GPS and GLONASS should be afforded protection in the 1574.397-1576.443 MHz and 1598-1606 MHz bands as proposed in LQP's proposed revision of the Commission's proposed rule Section 25.213

(b) above.

- Above 1610 MHz, GLONASS should only be protected as proposed in LQP's proposed revision of the Commission's proposed rule Section 25.213 (c) above.

- At future ITU World Radio communication Conferences seek to modify Radio Regulation 731E to be similar to LQP's proposed revision of the Commission's proposed rule Section 25.213 (c) above.

- Encourage the Russian GLONASS Federation to populate the GLONASS constellation with satellites operating in an anti-podal manner on channels 1 through 6, such that they will be protected as part of GNSS.

- Encourage the Russian GLONASS Federation to implement its planned frequency revision as quickly as possible to reduce interference into the Radio Astronomy Service.

- Advise the Russian GLONASS Federation that the US Government intends to promote MSS operations on a worldwide basis in the 1610-1626.5 MHz band and will grant licenses to US MSS operators in the near future to operate over this entire band.

- Improved GNSS receiver design specifications.

2.3 Sharing with the Terrestrial Services

2.3.1 Fixed Services in the 2483.5-2500 MHz Band

2.3.1.1 Protection for the Fixed Services in the 2483.5-2500 MHz Band

The GLOBALSTAR system was initially designed to operate within the power flux density (pfd) limits of RR 2566 as described in its application. However, during the NRM it was shown[6] that a slightly higher pfd limit would allow multiple CDMA MSS systems to share the same spectrum in co-coverage service areas. Without this slight increase in pfd, each CDMA system would not be able to achieve the capacity objectives

[6] Annex 2.1 Default Coordination Values of the Final Report of the Majority of the Active Participants of Informal Working Group 1 to Above 1 GHz Negotiated Rulemaking Committee, April 6, 1993.